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J. Nguyen
University of Wollongong

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Abstract

The study analyses the applicability of the efficient market hypothesis to the foreign exchange market by testing the profitability of the filter rule on the spot market. The significance of the returns was validated by comparing them to the returns from randomly generated shuffled series via bootstrap methods. The results were surprising. For the total period (1984-2003) small filter rules could deliver significant returns indicating an inefficient foreign exchange market. However, once the data was separated into four sub-periods of five years to test the stability of the returns, the results indicate that only the first sub period delivered significant returns. In the last two sub periods or ten years, the returns from employing filter rules were negative. This supports the conclusion that the efficient market hypothesis is valid in the foreign exchange market.

Keywords: Efficient market hypothesis, foreign exchange market, filter rules

1. Introduction

It has been suggested by Obstfeld and Rogoff (2000) that the exchange rate is the single most important relative price in an economy, since it potentially feeds back immediately into such a large range of transactions. However, since the adoption of floating exchange rate regimes in the 1970s and 1980s, observed deviations in short and medium-term exchange rates have been much too volatile to be explained by fundamental based exchange rate theory.

A possible reason for the breakdown between fundamentals and observed exchange rate changes is the fact that exchange rate models assume that market forces of arbitrage and speculation drive exchange rates back to their fundamental values [Friedman (1953)]. As such, these market forces ensure that the efficient market hypothesis stands. Fama (1991) defines an efficient market as one in which deviations from the extreme version of the efficient market hypothesis can be explained within information and transactions costs. That is, the efficient market hypothesis assumes that all available information that is relevant to the fundamental value of the exchange rate will, by the actions of rational traders, be incorporated into the value of a currency. Given this, in the absence of any new and relevant information, exchange rates will reflect their fundamental values and there will be no opportunities for profitable trading.

It is the aim of this paper to test the time series behaviour of exchange rates. An efficient market implies a random behaviour by exchange rates and thus, no risk-adjusted profits should be generated by following mechanical rules for generating trade signals. The study will test the validity of the efficient market hypothesis by testing whether filter rules can generate unusual returns. The significance of the results will be determined by the application of bootstrap methods. The study will generate thousands of new series of random exchange rate paths, with each new series constructed from the random reordering of the original exchange rate series. This allows us to compare the significance of the returns from the original series to the empirical distribution of results derived from the randomly generated series.

The results from the analysis for the sample period as a whole (1984-2003) supported the majority of past studies that found that the efficient market hypothesis did not hold for the foreign exchange market. The ability of small filter rules to deliver not just profits but significant returns for three of the four currencies indicated the existence of an inefficient market. However, subsequent applications of technical analysis over sub periods exposed the previous results as misleading. Technical analysis was only found to be profitable in the first sub period (1984-1988) after the adoption of a floating regime. Results from subsequent sub periods found that technical analysis could not return significant profits with any filter size. Returns from the first sub period were so large that they dominated the returns from other periods, thus giving a misleading conclusion that small filter rules could generate profits over the entire period. Thus, it is now evident that technical analysis cannot deliver significant returns over the last decade. Contrary to most studies, the results indicate that the efficient market hypothesis does hold for the foreign exchange market.

Section 2 of the study will look at the theoretical foundation of the efficient market hypothesis and its implications to the foreign exchange market. Section 3 will investigate the previous empirical research done on the validity of the efficient market hypothesis. The data and methodology of the study will be provided in section 4. Section 5 will outline the empirical results and section 6 provides the summary and conclusions of the study.

2. The Efficient Market Hypothesis

As stated, an efficient market is one in which observed exchange rate deviations from their long run value can be explained within information and transactions costs. As such, in the absence of any new and relevant information, exchange rates will reflect their fundamental values and there will be no opportunities for profitable trading. Thus, excess returns from trading can be defined as:

$$z_{j,t+1} = r_{j,t+1} - E(r_{j,t+1} | I_t) \tag{1}$$

where $r_{j,t+1}$ is the actual one period rate of return for holding currency j in the period ending at time $t+1$ and $E(r_{j,t+1} | I_t)$ is the expected value of that return conditional on the information set available at time t. According to equation (1), the foreign exchange market is efficient if, on average, expectational errors are zero $[E(z_{j,t+1} | I_t) = 0]$ and these errors follow no pattern that might be exploited to produce profits ($z_{j,t}$ is uncorrelated with $z_{j,t+k}$ for any value of k).

The greatest problem with empirical research on exchange rates is whether there is the existence of a risk premium, and if so, how to measure it. In the monetary model of exchange rates, domestic and foreign currency bonds are assumed to be perfect substitutes once the interest differential between foreign and domestic assets offsets the foreign exchange rate change. In this case, there is no exchange rate risk premium, and any sustained speculative trading profits would be deemed a violation of market efficiency. However, in the portfolio balance model of exchange rates, domestic and foreign bonds are assumed to be imperfect substitutes. Thus, in equilibrium, investors require a risk premium, in addition to the expected exchange rate change due to interest rate differentials, to compensate them for uncertainty of exchange rate changes. In this case, some level of positive profits from speculative trading would be consistent with equilibrium.

Thus, excess returns would now be defined as:

$$z_{j,t+1} = P_{j,t+1} - RP_t \tag{2}$$

where $P_{j,t+1}$ is the profit for holding currency j at time $t+1$ and RP_t is the risk premium required at time t.

In practice, most studies have not taken the risk premium explicitly into account as the difficulty has been distinguishing returns as a result of market inefficiency or fair compensation for risk.

3. Past Empirical Evidence

The primary technique for testing the efficiency of the foreign exchange market has been to compute the profitability of various mechanical trading strategies. The two trading rules most commonly tested are the filter rule [Dooley and Shafer (1976, 1983), Sweeney (1986), Levich and Thomas (1991), and Neely *et al.* (1997)], and the moving average rule [Schulmeister (1988), Levich and Thomas (1991), and Neely *et al.* (1997)]. The filter rule generates buy and sell signals by the following: “buy a currency whenever it rises x percent above its most recent trough; sell the currency and take a short position whenever the currency falls x percent below its most recent peak”. The moving average rule generates buy and sell signals based upon a crossover between short-term and long-term moving averages of past exchange rates. According to this rule, when the short-term moving average penetrates the long-term moving average from below (above) a buy (sell) signal is generated. The following section will look at past empirical studies that have investigated the returns from employing trading rules.

Dooley and Shafer (1983) report the filter rule trading profits for nine currencies using daily spot rates over the 1973 to 1981 period. Dooley and Shafer found that small filter rules from one to five percent were profitable for all the currencies over the entire sample period. However, the authors found that there was an element of risk in these trading rules, as each filter would have generated losses in at least one currency during at least one sub-period. As well, the results of Dooley and Shafer need to be interpreted with caution, as they did not report any measure of statistical or economic significance in their study.

Sweeney (1986) employed a similar filter rule technique for ten currencies over the April 1973 to December 1980 period. Profits from the filter rule were evaluated against a benchmark of buying and holding the foreign currency. Sweeney found that filter rules of 0.5, 1, 2, 3, 4, 5, and 10 percent led to profits in more than 80 percent of the cases. Under the assumption of constant exchange rate volatility, Sweeney calculated that in one third of the cases, the profits from the trading rules were statistically significant.

Schulmeister (1988) tested the profitability of the moving average rule for the US dollar-Deutschmark between April 1973 and September 1986. The study found that this trading strategy generated profits after adjusting for interest expenses and transaction costs. Schulmeister concluded that once an exchange rate moved, it was likely to proceed more or less uninterrupted, which allowed technical analysis to return profits.

Engel and Hamilton (1990) modelled the time-varying nature of exchange rate distribution as a Markov switching process. They found that from1973 to 1988 the long swings hypothesis of exchange rate movements fitted the data significantly better than a state independent model of a single distribution. This implied that exchange rate movements exhibited properties that would suggest uninterrupted trends, which could be exploited by trading rules.

Levich and Thomas (1991) tested the profitability and statistical significance of both the filter rule and moving average rule for currency futures contracts for the period 1976 to 1990. Using bootstrap methodology, Levich and Thomas constructed a random reordering of the exchange rate movement. The significance of the profits generated by technical analysis in the original data was then compared to the results derived from the randomly generated series. Levich and Thomas' results suggest that simple technical trading rules have often led to profits that are highly unusual, even after accounting for transactions costs.

Neely *et al.* (1997) investigate the profitability of both the filter rule and the moving average rule through the application of genetic programming. This allows the authors to construct an out-of-sample test of the significance of the excess returns earned by the trading rules. They found strong evidence of economically significant excess returns after transaction costs for the five currencies studied between 1975 to 1980.

Fiess and MacDonald (1999) use multivariate co integration methods to test whether the specific intra-day High and Low prices and Closing prices of a currency contain any information about future price developments, namely the next day's opening price. Using the Stochastics introduced to financial economics by Lane (1984), the authors generate trading signals based upon the currency's High, Low and Closing prices. Using daily data from August 1986 to August 1996 for the US dollar against the deutschmark and the yen, the authors found that their model beat the simple no change forecast model. Their model correctly predicted the direction of the currency change 55.8 percent of the time for the US dollar/deutschmark, and 57.3 percent of the time for the US dollar/yen. Converting the Stochastic model into a trading rule to test its profitability and comparing it to a buy and hold strategy, the authors found that the model beat the buy and hold strategy. Thus, the authors conclude that using intra-day High, Low and Closing prices may provide some insight into the future direction of a currency. This conclusion is in stark contrast to the conclusions implied by efficient market hypothesis.

Osler (2000) tests the ability of technical trading signals supplied by six foreign exchange trading firms to assist in predicting intraday trend interruptions. Each day, the six firms provide to their customers their projected "support and resistance" levels of exchange rate movements for the day. From January 1996 through to March 1998, using one minute interval exchange rate quotes for the US dollar against the yen, the deutschmark and the pound, Osler found that support and resistance levels supplied by the six foreign exchange trading firms provided valuable information. The study found that, on average, exchange rates bounced off arbitrary or randomly picked support and resistance levels 56.2 percent of the time. By contrast, exchange rates, on average, bounced off the published support and resistance levels 60.8 percent of the time. Thus, Osler concludes that the firms seem to have an ability to predict exchange rate bounces, which is contrary to efficient market hypothesis.

In contrast to the general trend, Curcio *et al.* (1997) found that technical analysis did not generate profits, especially once transactions costs were taken into account. The authors used hourly intra-day quotes of the spot exchange rate for the US dollar against the yen and the deutschmark. Using two data samples, (sample A covering the period from 10 April 1989 to 29 June 1989 and sample B covering the period 31 January 1994 to 30 June 1994), the authors found that technical analysis was profitable in the first period. However, once transaction costs were taken into account, the profits disappeared. The authors found that technical analysis generated a loss in the second time period, even before transactions costs were accounted for.

Chang and Osler (1999) investigate the profitability of technical analysis using the head-and-shoulders pattern. They construct an algorithm for identifying and trading on head-and-shoulders patterns. The head-and-shoulders strategy essentially assumes that an earlier upward trend is about to be reversed and vice versa once a head-and-shoulders pattern can be identified. Using daily spot rates for six currencies between March 1973 to June 1994, the authors found that the trading rule was not profitable for four out of the six currencies.

The study by Rubio (2004) is perhaps the most indicative research supporting efficient market hypothesis. Using US dollar quotes against the Australian dollar, Canadian dollar, yen, franc, and pound, between the period January 1975 to June 2004, Rubio investigates the profitability of eight different trading rules. Each strategy is then compared to the simple buy and hold strategy. Rubio found that, once transactions costs are taken into account, the top strategy only returned 2.75 percent per annum in excess to indexation (buy and hold). For all currencies, the average return was only 0.06 percent per annum above indexation. Rubio found that buy and sell signals generated from these trading rules generated excessive trading, which decimated any profits.

The empirical evidence indicates that the issue of efficient market hypothesis is far from settled. Proponents of technical analysis often cite Dooley and Shafer (1983), Sweeney (1986), and Neely *et al.* (1997) as evidence that trading rules can make systematic profits over and above transactions costs. As such, they claim that the foreign exchange market is far from efficient, and that past prices do provide insight into future prices. In contrast, recent studies, and in particular Rubio (2004), appear to indicate that the foreign exchange market is efficient. These results provide some comfort for exchange rate theorists.

It is the aim of this study to investigate whether technical analysis provides insight into the foreign exchange market, and specifically whether the efficient market hypothesis holds for the Australian foreign currency market. Thus, the present study would go some way into addressing the unresolved issue of efficient market hypothesis.

4. Data and Methodology

The Study has collected the spot exchange rate for four foreign currencies for the period of January 3, 1984 through to December 31, 2003. Unlike previous studies that looked at earlier time periods, the starting period was picked as the Australian dollar was floated in late 1983. The currencies to be examined are the United States dollar (US), the British pound (BP), the Japanese yen (JY), and the Swiss Franc (SF). These currencies were selected as they are the most heavily traded currencies. This limits the most common issue of liquidity as a reason why assets may not reflect their fundamental value. Data for the Euro was not collected to keep the timeframe of the analysis uniform.

The data source was obtained from the Reserve Bank of Australia. The spot exchange rate quotes shown for the US dollar is a representative mid-point determined by the Reserve Bank on the basis of quotations in the Australian foreign exchange market at 4:00 pm Eastern Australian time on the day concerned. The rates shown for the other currencies are calculated by crossing the rate for the US dollar with mid-points of buying and selling rates quoted in Australian or Asian markets at the same time.

In order to test the profitability of technical analysis, the study will analyse the profitability of the filter rule. The study will utilise the filter rules of size x = 0.5%, 1%, 2%, 3%, 4%, and 5%.

The Study will focus on the profitability of the filter rule as technical models employing filter rules are the most popular trading strategies that have been used in earlier studies. Using the filter rule implies that traders are attempting to profit from long, relatively uninterrupted, swings in a currency. The filter sizes are selected as they have been applied in earlier studies. Other filter sizes or trading rules can be analysed. However, data-mining exercises to find a profitable trading rule or filter size should be avoided.

Thus the null hypothesis is as follows:

Null Hypothesis 1: Assuming no foreign exchange risk premium, profits from applying the filter rules should equal zero after accounting for transactions costs.

If the null hypothesis is rejected, then this indicates the efficient market hypothesis does not hold or the existence of a risk premium.

For each currency, the Study, using the bootstrap approach, generates a new reshuffled series, by making a random rearrangement of price/quote changes in the original series. By randomly rearranging the original data, the new series is constrained to have identical distributional properties as the original series. Therefore, the simulation generates one of many paths that the exchange rate might have followed from its level on the starting day of the sample until the ending day, holding constant the original distribution of exchange rate quote changes. This process of randomly shuffling the series of returns without replacement is repeated one thousand times for each currency in the twenty year time period. Hence, for each currency, there are one thousand possible sequences or paths the exchange rate may have taken in the twenty year period. Each filter size trading rule is then applied to each of the one thousand random series and the profits are measured.

The profits of the original series can be compared to the profits from the randomly generated, shuffled series. Thus, the null hypothesis is as follows:

Null Hypothesis 2: If there are no signals in the foreign exchange market then profits obtained from trading in our original data series should not be significantly different from the profits attained in the randomly generated shuffled series.

The null hypothesis 2 is rejected if the profits returned from the original data series are greater than the profits returned from our empirical distribution.

5. Empirical Results

The following table provides the descriptive statistics of the original time series of the spot exchange rate returns. The table provides the descriptive statistics for the twenty year time period as well as the descriptive statistics for the four sub-periods. The descriptive statistics provides the properties of the daily returns or the change in the daily spot rates.

Table 1: Sample Statistics of Daily Returns: Foreign Exchange

Currency	Variable	Full Sample	1984-88	1989-93	1994-98	1999-2003
US	N	5057	1265	1270	1266	1253
	Mu	-0.000015	-0.000016	-0.000173	-0.000073	0.000185
	Sigma	0.006430	0.007300	0.005409	0.005731	0.007076
	Skewness	-0.42	-0.82	-0.73	0.10	-0.13
BP	N	5057	1265	1270	1266	1253
	Mu	-0.000047	-0.000179	0.000011	-0.000159	0.000132
	Sigma	0.007832	0.008260	0.008810	0.007169	0.006922
	Skewness	0.03	-0.34	0.31	0.13	-0.03
JY	N	5057	1265	1270	1266	1253
	Mu	-0.000155	-0.000493	-0.000245	-0.000037	0.000151
	Sigma	0.008329	0.007775	0.007581	0.009185	0.008643
	Skewness	-0.36	-0.75	-0.38	-0.35	-0.13
SF	N	5052	1265	1267	1264	1253
	Mu	-0.000109	-0.000295	-0.000154	-0.000105	0.000114
	Sigma	0.008863	0.008672	0.009388	0.009490	0.007768
	Skewness	-0.18	-0.49	-0.08	-0.04	-0.17

N = number of logarithmic returns

From Table 1 it can be seen that the average daily returns for all the currencies is relatively small and averages near zero. The largest absolute mean return for the full sample period was only around one and a half basis points per day for the Japanese yen, or approximately 4 percent per annum. The average daily change in the spot rate for the other currencies was much lower. The average daily change in the spot rate was around one basis point, half a basis point, and less than a quarter of a basis point for the Swiss franc, the British pound, and the US dollar respectively.

For the full sample period, the daily standard deviation varies from 0.64 percent for the US dollar to 0.89 percent for the Swiss franc. Therefore, this would imply that the US dollar is the least volatile of the foreign currencies. However, the daily standard deviations are relatively similar for all currencies, implying that there is no significant difference in volatility.

Looking at the sub periods, there appears to be no discernable pattern with regards to volatility (or sigma). For the US dollar, volatility is high for the first and last sub periods. The British pound exhibits decreasing volatility over time while the Japanese yen exhibits increasing volatility over time. For the Swiss franc, volatility appears to be greatest in the middle two sub periods.

The profits associated with the generation of buy and sell signals using the filter rules are reported in the following table.

Table 2: Profitability of Filter Rules, Percent Per Annum (Sample Period, January 1984-December 2003)

Currency Sample size	**Filter Size (%)**						
	0.5	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**Average Profit**
US (N=5057)							
Actual Profit P/A	-0.98	0.67	0.14	-1.02	-0.94	-3.46	**-0.93**
Total no. of trades	1090	496	136	35	17	5	
BP (N=5057)							
Actual Profit P/A	6.96	3.72	-1.58	-1.72	0.33	-2.03	**1.62**
Total no. of trades	1278	671	249	103	36	22	
JY (N=5057)							
Actual Profit P/A	5.62	6.14	3.48	-0.77	3.62	0.24	**3.10**
Total no. of trades	1322	676	250	105	39	23	
SF (N=5052)							
Actual profit P/A	3.90	3.25	-1.13	5.16	2.20	-6.04	**1.22**
Total no. of trades	1404	792	325	121	56	26	

Note: N is the number of logarithmic returns
P/A represents per annum

The profits, in terms of average returns per annum, associated with the filter rules show a surprising result. The results indicate that not one currency exhibits profits for all filter sizes.

For the entire twenty year sample period, the filter rules were, on average, profitable for the British pound, Japanese yen and Swiss franc only. As well, the average profit for the British pound and Swiss franc were relatively small, at 1.62 percent and 1.22 percent respectively. The Japanese yen generated the largest average profit return of 3.10 percent per annum. In contrast, the filter rule for the US dollar, on average, actually generated losses. This implies that the efficient market hypothesis may hold for the US currency market. The results appear to indicate that filter rules, on average, may not be as profitable as suggested by other studies.

Table 2 also suggests that, on average, smaller filter rules appear to be more profitable than larger filter rules for the British pound, Japanese yen and Swiss franc. This is in line with other studies [Dooley and Shafer (1983), Sweeney (1986), and Levich and Thomas (1991)]. Concentrating on the British pound, Japanese yen and Swiss franc, the 0.5 percent and 1 percent filter sizes generated relatively large profits over the twenty year period. For these currencies, filter sizes at 2 percent and above generated losses or relatively lower profits.

These results appear to indicate that, for these currencies, the spot rate does go in swings or move in a pattern, which may be taken advantage of by smaller filter sizes. However, the market appears to adjust relatively quickly, so that larger swings are not common, and hence the inability of larger filter sizes to generate profits. Thus, it seems that while the speed of adjustment in the spot rate appears to be slow enough for small filter rules to deliver profits, the speed of adjustment appears to be sufficiently efficient to render larger filter sizes inoperative.

For the US dollar, there appears to be no noticeable pattern between the filter size and the profit return, or loss minimisation. Thus, contrary to the results for the other currencies, this further reinforces the validity of the efficient market hypothesis for the US currency market.

As uncovered interest rate parity implies no excess returns above transactions costs, the profitability of the trading rules needs to account for transactions costs. With regard to the foreign exchange market, there are two categories of transactions costs. The first transaction cost is the bid/ask spread, which is assumed to be $0.0001 per transaction. The second transaction cost is the brokerage commission, which is assumed to be $11.00 per round-trip transaction. This is in line with other studies such as Dooley and Shafer (1983), Levich and Thomas (1991) and Neely *et al.* (1997). Therefore, it is assumed that the total transactions costs in the foreign exchange market are about 2.5 basis points (0.025 percent) per transaction. Given this, the following table provides the profitability of the filter rules after transaction costs are accounted for.

Table 3: Profitability of Filter Rules with Transaction Costs (Sample Period, January 1984-December 2003)

Currency Sample size	**Filter Size (%)**						
	0.5	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**Average Profit**
US (N=5057)							
Profit P/A before TC	-0.98	0.67	0.14	-1.02	-0.94	-3.46	-0.93
Total no. of trades	1090	496	136	35	17	5	
Profit P/A after TC	**-2.34**	**0.05**	**-0.03**	**-1.06**	**-0.96**	**-3.47**	**-1.30**
BP (N=5057)							
Profit P/A before TC	6.96	3.72	-1.58	-1.72	0.33	-2.03	1.62
Total no. of trades	1278	671	249	103	36	22	
Profit P/A after TC	**5.36**	**2.89**	**-1.89**	**-1.85**	**0.29**	**-2.06**	**0.46**
JY (N=5057)							
Profit P/A before TC	5.62	6.14	3.48	-0.77	3.62	0.24	3.10
Total no. of trades	1322	676	250	105	39	23	
Profit P/A after TC	**3.97**	**5.30**	**3.17**	**-0.90**	**3.57**	**0.21**	**2.55**
SF (N=5052)							
Profit P/A before TC	3.90	3.25	-1.13	5.16	2.20	-6.04	1.22
Total no. of trades	1404	792	325	121	56	26	
Profit P/A after TC	**2.14**	**2.26**	**-1.43**	**5.01**	**2.13**	**-6.07**	**0.67**

Note: N is the number of logarithmic returns
P/A is percent per annum
TC is transactions costs

As expected, small filters generate a considerably greater number of buy-sell signals, thus incurring higher transactions costs. It can be seen from Table 3 that once transactions costs are accounted for, the average profitability of the filter rules for all of the currencies, bar the Japanese yen, are decimated. The average annual loss for the US dollar is now 1.30 percent, while the average annual profit for the British pound and Swiss franc are 0.46 and 0.67 percent respectively. Thus, there appears to be insufficient evidence to reject the null hypothesis 1. That is, the average annual profits generated from the filter rules do not appear to be sufficient to conclude that excess profits can be generated over and above transactions costs and any exchange rate premium. Thus the empirical evidence from the foreign exchange market would appear to support the efficient market hypothesis.

Concentrating on the profitability of different filter sizes raises some hope for those who reject the validity of the efficient market hypothesis. Although smaller filter sizes generate a greater number of buy and sell signals, and thus imply greater transactions costs associated with greater trading volumes, profits generated from three out of the four currencies may still indicate some form of market inefficiency.

Profits from employing a 0.5 percent and 1 percent filter rule for the British pound and Japanese yen still generate profits, after transactions costs, which are relatively high. For the British pound, a 0.5 percent filter rule generates 5.36 percent profit per year, and a 1 percent filter rule generates 2.89 percent profit per year. For the Japanese yen, a 0.5 percent filter rule generates 3.97 percent profit per year, and a 1 percent filter rule generates 5.30 percent profit per year. Even after accounting for transactions costs, these returns are much higher than the returns generated from employing larger sized filter rules. Thus, for the two currencies, the results appear to indicate that the spot rate does move in a pattern, which may be taken advantage of by the smaller filter sizes. However, the spot rate for the Japanese yen and British pound appears to adjust relatively quickly and hence the ability of smaller filter rules to outperform the larger filter rules.

For the Swiss franc, the higher transactions costs associated with the smaller filter rules decimated profits to such an extent that the profits from employing smaller filters compared to larger filter rules were not distinguishable. The transactions costs decreased profits from most filter sizes to around 2 percent. Thus, it would appear that profits from the Swiss franc market are not significantly high enough to be able to reject the null hypothesis, or the validity of the efficient market hypothesis.

For the US dollar market, transactions costs reduced profitability of all filter rules to zero or negative returns. As well, the 0.5 percent filter rule generated the second largest average annual loss. This would be in line with the efficient market hypothesis and the random walk nature of exchange rates. The efficient market hypothesis implies that greater trading volumes would generate larger losses as market participants cannot predict future exchange rate movements without informational advantages. Thus trading on past prices cannot provide an advantage for an investor. Using filter rules merely creates ‘false’ trading signals and the greater the number of trading signals, the greater the transactions costs, and the greater the loss from trading.

Thus, evidence from the four currencies indicates that the null hypothesis cannot be rejected with confidence. While the Japanese yen and British pound currency markets appear to be sufficiently inefficient to be able to be exploited by smaller filter rules, the US dollar and Swiss franc currency markets appear to support the efficient market hypothesis.

In order to statistically validate the results, the returns from the original data will now be compared to the randomly reshuffled series. The following table ranks the return of profits generated by the filter rules in the original data against the profits generated in the randomly generated series. A ranking of one indicates that the profit from the original data beat all profits from the one thousand generated series. A ranking of one thousand indicates that the return from the original data was lower than the returns for all the randomly generated series.

Table 3: Profitability of Filter Rules- The Original Sample Ranked against the Randomly Generated Samples, (January 1984-December 2003)

Currency Sample size	**Filter Size (%)**						
	0.5	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**Average Profit**
US (N=5057)							
Actual Profit	-0.98	0.67	0.14	-1.02	-0.94	-3.46	-0.93
No. of trades	1090	496	136	35	17	5	
Rank	**652**	**377**	**458**	**643**	**642**	**941**	
BP (N=5057)							
Actual Profit	6.96	3.72	-1.58	-1.72	0.33	-2.03	1.62
No. of trades	1278	671	249	103	36	22	
Rank	**2***	**29***	**761**	**732**	**428**	**808**	
JY (N=5057)							
Actual Profit	5.62	6.14	3.48	-0.77	3.62	0.24	3.10
No. of trades	1322	676	250	105	39	23	
Rank	**27***	**10***	**115**	**627**	**137**	**509**	
SF (N=5052)							
Actual profit	3.90	3.25	-1.13	5.16	2.20	-6.04	1.22
No. of Trades	1404	792	325	121	56	26	
Rank	**43***	**72****	**687**	**17***	**127**	**997**	

Note: Profit as Percent Per Annum
* indicates top 5percent
** indicates top 10 percent

From Table 3 it can be seen that returns from the filter size 0.5 percent for the British pound, Japanese yen and Swiss franc all came in the top five percent. That is, the returns beat at least 95 percent of the randomly simulated series. As well, returns from the filter size 1 percent for the British pound and Japanese yen also ranked in the top 5 percent, while the return for the Swiss franc ranked in the top 10 percent. Aside from the 3 percent filter rule for the Swiss franc, the returns from all other filter sizes showed no significant returns when compared to the randomly shuffled series.Thus, it appears that only small filter rules (0.5 percent and 1 percent) for the pound, yen and franc deliver profits that are statistically significant. The sustained profits from these small filter rules in these markets indicates that these small filter rules capture the behaviour of the market participants whose actions create signals, and thus opportunities, for profitable trade. It appears that we can reject the null hypothesis 2 for small filter rules for the British pound, Japanese yen, and Swiss franc.

The returns for all filter sizes for the US dollar and the larger filter sizes for the other three currencies (2 percent and greater) was not significantly different to the profits attained in the randomly shuffled series. For these, the null hypothesis 2 cannot be rejected. Thus, there is no statistical evidence of information or signals in the original sequence of data that can be taken advantage of by technical analysis.

So far, the empirical work has focused upon the sample data as a whole. The study will now measure the stability of the filter trading rule over time. The sample has been split into four sub periods, each being five years in length. Each filter size trading rule is then applied to each sample period. The profitability of the filter rules for each sub period is given in the table below.

Table 4: Profitability of Filter Rules (sub-period), Percent Per Annum

Currency Sample size	**Filter Size (%)**						
	0.5	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**Average Profit**
US (N=5057)							
1984-1988	4.50	6.21	-0.91	-0.96	-4.59	-8.45	**-0.70**
(total trades)	(274)	(128)	(43)	(15)	(5)	(3)	
1989-1993	-4.36	-0.36	1.63	-1.05	1.62	3.1	**0.10**
(total trades)	(243)	(102)	(20)	(5)	(3)	(1)	
1994-1998	2.16	-1.04	2.18	1.9	-3.27	3.81	**0.96**
(total trades)	(244)	(115)	(25)	(8)	(6)	(2)	
1999-2003	-6.01	-1.86	-0.68	-1.98	4.09	-12.82	**-3.21**
(total trades)	(328)	(150)	(46)	(9)	(5)	(1)	
BP (N=5057)							
1984-1988	16.89	16.40	3.64	1.57	7.08	3.66	**8.21**
(total trades)	(314)	(154)	(65)	(34)	(10)	(8)	
1989-1993	6.56	4.82	1.41	-1.48	-5.59	-6.66	**-0.16**
(total trades)	(344)	(196)	(74)	(32)	(17)	(9)	
1994-1998	0.11	-4.23	-2.77	-4.91	3.00	0.59	**-1.35**
(total trades)	(312)	(164)	(55)	(23)	(4)	(1)	
1999-2003	4.00	-2.32	-7.32	-0.30	-0.36	-6.27	**-2.10**
(total trades)	(306)	(157)	(53)	(13)	(4)	(4)	
JY (N=5057)							
1984-1988	14.00	11.16	13.48	15.89	15.42	6.14	**12.68**
(total trades)	(280)	(138)	(41)	(17)	(8)	(8)	
1989-1993	11.40	10.82	7.21	-2.02	1.72	0.94	**5.01**
(total trades)	(302)	(148)	(54)	(26)	(5)	(5)	
1994-1998	-1.77	-0.29	2.72	-16.36	-4.71	-0.87	**-3.55**
(total trades)	(385)	(201)	(77)	(39)	(15)	(9)	
1999-2003	-1.08	2.95	-7.55	4.36	2.00	-3.95	**-0.54**
(total trades)	(354)	(188)	(76)	(21)	(13)	(3)	
SF (N=5052)							
1984-1988	20.00	23.33	3.39	13.85	15.74	1.36	**12.95**
(total trades)	(308)	(158)	(76)	(29)	(13)	(6)	
1989-1993	-6.68	-3.41	-4.52	8.19	6.10	-7.01	**-1.22**
(total trades)	(397)	(225)	(91)	(24)	(14)	(10)	
1994-1998	-2.49	-6.06	-3.86	2.32	-6.42	-13.30	**-4.97**
(total trades)	(378)	(222)	(90)	(37)	(19)	(7)	
1999-2003	4.84	-0.61	1.89	-1.99	-5.09	0.96	**0.00**
(total trades)	(318)	(184)	(65)	(31)	(12)	(4)	

From Table 4 it can be seen that in the first sub period (1984-1988) for the US dollar, returns from technical analysis exhibits the same patterns as the previous results for the other currencies. That is, small filter rules up to one percent delivers relatively large profits, while larger filter rules do not return profits. This may suggest that, in the first sub period, price movements for the US dollar exhibited some degree of dependence that is captured by the smaller filter sizes. However, returns from the filter rules in the subsequent periods were negative or close to zero. This further reinforces the validity of the efficient market hypothesis in the market for US currency and supports the conclusion implied from the efficient market hypothesis.

From Table 4 the returns for the British Pound, Japanese yen, and Swiss franc indicate a remarkable result. For these three currencies, the average profitability of the filter rules is significantly higher in the first sub-period than in any other period. In the first sub period, the average return for the British Pound, Japanese yen, and Swiss franc were 8.21 percent, 12.68 percent and 12.95 percent respectively. These profits, however, disappeared rapidly in subsequent sub periods. For the last two sub-periods, profitability is negative or equal to zero for all three currencies.

The results of our sub periods have profound implications to our previous results. While we had previously claimed that technical analysis may provide insight into short term exchange rates, the results here indicate the contrary. The inability of any filter size to deliver significant profits above transactions costs in the last two sub periods, or ten years, supports the efficient market hypothesis, which, in its strong form at least, initially appeared to be invalid.

The results from analysing the sub periods raise some important issues which must be addressed. The first issue concerns why the results from the full sample period differ so dramatically from the sub period results. The second, and more important issue, is why returns from the first sub period differ so dramatically from the other subsequent sub periods. The third, and equally important issue, relates to why the results here differ from many previous studies that have found technical analysis, and even filter rules, to be profitable.

Addressing the first issue is straight forward. Profits from small filter sizes were so large in the first sub period that they more than offset the losses incurred in the subsequent periods, which were close to zero, as implied by the efficient market hypothesis. Thus, for our entire sample period, small filters, on average, still delivered significant returns, although these returns were due to profits from only one sub period.

This is linked to our second issue concerning why the returns from the first sub period differ so dramatically from the other subsequent sub periods. There are two possible, and very reasonable, explanations for this phenomenon. The efficient market hypothesis requires that all available information that is relevant to the fundamental value of the exchange rate will be incorporated into the value of a currency. Hence, for the efficient market hypothesis to hold there needs to be homogenous information and sufficient liquidity. The Australian dollar was floated in December 1983. As such, it would be reasonable to assume that there would be a learning period whereby traders are processing information and attempting to ascertain the true value of the dollar. During this period, traders face uncertainty and are slow to process information, causing exchange rates to depart from their true, as yet unknown, long run value. Thus, the initial inefficiency in the foreign currency market allowed technicians to profit from employing simple filter rules. However, as time passes and traders learn about the Australian dollar, its price or value more correctly reflects its long term value. As such, trading rules will fail to deliver significant returns as the value of the Australian dollar reflects all relevant information and the foreign exchange market more closely resembles an efficient market.

The second requirement for the efficient market hypothesis is the assumption of liquidity, so that values are truly reflective of market forces. In economics, it is always assumed that the foreign currency market is sufficiently liquid so that prices reflect these market forces. However, it may be reasonable to argue that, upon the floating of the Australian dollar, turnover may not have been sufficient to ensure the efficient market hypothesis. The following table provides the daily average turnover of global foreign exchange, as printed by the Bank of International Settlements.

Table 5: Global Foreign Exchange Market Turnover (Daily average in billions of US dollars)

	1989	1992	1995	1998	2001	2004
Total traditional turnover	590	820	1,190	1,490	1,200	1,880
Percentage share for the Australian dollar	1	1.3	1.4	1.6	2.1	2.8

Source: Bank of International Settlements (2004)

Although the survey started recording data from 1989 (as opposed to the desired 1984), it is evident that both the level of turnover in foreign exchange, and proportion of the exchange involving the Australian dollar, has risen substantially. From the trend, one can draw inferences that at the start of the float period, turnover in the Australian dollar may not have been sufficient for prices to reflect their fundamental values. As such, there may have been opportunities for trading rules to exploit slowly adjusting prices. However, as turnover, and thus liquidity, increases over time, prices reflect their true value and opportunities for technical analysis disappear.

Whatever the reason, it does appear evident that opportunities for profitable trading through technical analysis are no longer available. However, this begs the last and most important question. Contrary to past studies, why then, has this study found technical analysis to be unprofitable, especially in the last three sub periods or fifteen years?

Section 3 of the study covering the past empirical evidence showed that the results of Dooley and Shafer (1983), Sweeney (1986), and Levich and Thomas (1991) found that filter rules can generate profits in excess of transactions costs. In contrast, Curcio *et al.* (1997) and Rubio (2004) found that filter rules could not generate profits in excess of transactions costs. The apparent contradiction in the conclusions of these studies can be explained by the results found in this Study. The sample years tested by Dooley and Shafer were between 1973 and 1981. Sweeney's sample years were between 1973 and 1980. Levich and Thomas applied the filter rule between 1976 and 1990. These studies support the conclusion that the foreign exchange market was in fact inefficient and that filter rules could generate profits. The present study also found that filter rules could generate profits in the earlier periods (1984-1988). Thus, during the early years of floating exchange rate regimes, foreign currency markets were in fact inefficient, thus providing opportunities for technicians to profit by employing simply trading rules.

However, as financial markets evolve over time and investors become better informed, inefficiencies become less apparent and profitability from trading rules disappear. Curcio *et al.* (1997) concentrate on market efficiency in 1989 and 1994, with the returns from the latter year being negative, as opposed to 1989 where the return was slightly positive (but insufficient to account for transactions costs). Rubio's (2004) sample period looked at returns between 1975 and 2004, with the finding that there were no significant returns over the entire sample period. Thus, while the profitability of technical analysis indicated the existence of an inefficient foreign exchange market in the earlier sub periods, the inability of technical analysis to deliver returns in the last decade indicates the contrary.

In hindsight, the results of this Study were perhaps first inadvertently recognised or identified in the results of Levich and Thomas (1991). While that study is often cited as empirical evidence of an inefficient foreign exchange market, the authors found that "on average, there is some deterioration over time in the profitability of these rules, but the overall decline is small" [Levich and Thomas (1991) p. 20]. Using a more current data set, the present Study found that deterioration in the profitability of trading rules is perhaps more prevalent than first recognised by the authors. Perhaps the financial markets, and especially the foreign currency market, has evolved so quickly, and the volume of trade expanded so rapidly, that evidence of inefficient markets only ten to fifteen years ago are no longer relevant to today's financial environment. This has been the major implication derived from the empirical results of the present Study.

6. Summary and Conclusions

The Study asked the question of whether the efficient market hypothesis was applicable to the foreign exchange market. Concentrating on the analysis for the sample period as a whole, it was initially reasoned that the foreign exchange market exhibited some characteristics associated with an inefficient market. The ability of small filter rules to deliver not just profits but significant returns for three of the four currencies indicated that technical analysis could deliver profits, contrary to the conclusion implied by the efficient market hypothesis.

However, subsequent applications of technical analysis over sub periods exposed the previous results as misleading. Technical analysis was only found to be profitable in the first sub period after the adoption of a floating regime. Results from subsequent sub periods found that technical analysis could not return significant profits with any filter size. Returns from the first sub period were so large that they dominated the returns from other periods, thus giving a misleading conclusion that small filter rules could generate profits over the entire period. However, it is now evident that technical analysis cannot deliver significant returns over the last decade. Contrary to most studies, the results indicate that the efficient market hypothesis does hold for the foreign exchange market. Thus, our null hypothesis one that 'assuming no foreign exchange risk premium, profits from applying the filter rules should equal zero after accounting for transactions costs' cannot be rejected. As well, our null hypothesis two that 'there is no information or signals in the original sequence of data and that profits obtained from trading in the original series should not be significantly different from the profits attained in the shuffled series' cannot be rejected too.

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